D.2 INTERDISCIPLINARY EXPLORATION SCIENCE PROGRAM

1. Scope of Program

1.1 Programmatic Background

The Vision for Space Exploration provides NASA with goals and objectives that motivate a long-term program of science and exploration. In 2004, NASA began the process of transforming its organization and programs to successfully implement the exploration program.

The Vision for Space Exploration identifies several specific goals and objectives for space exploration beyond low Earth orbit. These include (among others):

- Undertake lunar exploration activities to enable sustained human and robotic exploration of Mars and more distant destinations in the solar system;
- Use lunar exploration activities to further science, and to develop and test new approaches, technologies, and systems, including use of lunar and other space resources, to support sustained human space exploration to Mars and other destinations;
- Conduct robotic exploration of Mars to search for evidence of life, to understand the history of the solar system, and to prepare for future human exploration;
- Conduct robotic exploration across the solar system for scientific purposes and to support human exploration. In particular, explore Jupiter's moons, asteroids and other bodies to search for evidence of life, to understand the history of the solar system, and to search for resources; and
- Conduct advanced telescope searches for Earth-like planets and habitable environments around other stars.

Additional information on the Vision for Space Exploration may be found at http://www.nasa.gov/missions/solarsystem/explore_main.html.

The organizational transformation of NASA in 2004 brought together the former Offices of Earth and Space Sciences into a single Science Mission Directorate. All of the research focus areas and science themes of the Earth and space science programs have been combined into three integrated science programs: Earth-Sun System, Solar System, and Universe. Additional information on the research programs and science management structure of the Science Mission Directorate may be found at http://science.hq.nasa.gov.

The combination of the organizational transformation of NASA's science program management with the articulation of the Vision for Space Exploration has created an opportunity to develop a set of interdisciplinary research themes for science investigations in support of the Vision for Space Exploration. Interdisciplinary research themes are expected to cross traditional discipline boundaries, especially boundaries between SMD science themes (e.g. Earth-Sun System, Solar System, Universe) or between Earth science and space science.

It is not NASA's intent to pursue new interdisciplinary scientific investigations at the expense of our high priority Earth and space science activities. The intent is to take full advantage of the breadth and depth of experience, knowledge and capabilities that exist in NASA sponsored research to forge new and innovative areas of scientific inquiry into the Universe, Solar System (including Earth), and the Sun in such a way that the whole program contribution is greater than sum of its very exciting and successful parts.

The Interdisciplinary Exploration Science (IES) Program solicits investigations that are interdisciplinary in nature and enable, or are enabled by, NASA's program of space exploration.

1.2 Programmatic Description

An important role of the Science Mission Directorate in NASA's program of space exploration is to identify, foster, and support science investigations that enable exploration as well as science investigations that are enabled by exploration. The combination of Earth and space science into a single Science Mission Directorate provides an opportunity to promote interdisciplinary research themes.

The IES Program solicits science investigations that are (i) relevant to the objectives of NASA's exploration program as described in the Vision for Space Exploration and (ii) interdisciplinary in nature. Proposals are solicited for investigations to carry out lines of scientific inquiry that could connect the goals of the Vision for Space Exploration to the ongoing, but more narrowly focused, scientific activities within Earth system science, planetary sciences, astrophysics, and solar physics. Investigations that involve joint research efforts by investigators from different scientific communities, particularly from both Earth and space science, are especially encouraged.

The IES program does not replace but supplements the exciting and high priority research investigations that are sponsored by the Mission Science Divisions within the Science Mission Directorate. Science investigations which are appropriate to science themes within NASA's research program should be directed to the research programs described in Appendices A (Earth-Sun System), B (Solar System), and C (Universe) of this NRA.

1.3 Notional Research Focus Areas

In response to a November 2004 request from NASA, the science community has suggested research themes for interdisciplinary exploration science investigations. Investigations are solicited in these or any other appropriate research areas. Proposed investigations may include, but are not limited to:

- The interrelationship between terrestrial life, climate, and other physical parameters (e.g., tectonics, extraterrestrial impacts or high-energy radiation events) across time (evolutionary history), spatial scales (prokaryotic to macromulticellular life), or levels of organization (genome, organism, ecosystem) as a requisite precursor for informing our understanding of the breadth of

environments capable of promoting habitability and sustaining life on other worlds (or regions of other worlds) and how these environments change over time. The development of niche models projecting the distributions of various forms of life (including extremophiles) is welcome as such models may result in more effective life detection tools for exploration (be they focused on fossil, extant, or spectroscopic evidence of life, modeled organisms, or simulations using populations in the laboratory). The goal is to refine our understanding of the spatial and temporal contexts of life here on Earth in order to develop tools for finding life elsewhere.

- Research on signatures of extraterrestrial life, whether remotely sensed or sought *in situ*. Specific topics include extant or extinct microbial life that could be detected and studied by means of remote, *in situ*, or sample analysis investigations (e.g. mineralized biosignatures of ancient microbial life on Earth and biosignatures of Earth's extant microbial communities as well as the processes that produce these biosignatures). Research topics could also include the detection of microbial biosignatures on extrasolar planets, on planets in any solar system, and in samples of extraterrestrial material on Earth. Additionally, the scope of this research area could include a study and characterization of the integrated Earth signatures for biological activity, investigation of potential nonbiological processes for producing what are commonly thought to be indicators of life, investigations into the variation of biomarker signals from extrasolar planets with environment and over time (orbital induced variations, compositional induced variations, etc.).

- Research towards understanding the history of the solar system and the planets as a system of systems. Specific topics may include the relationship between the three regions of the solar system (terrestrial planets, giant planets, and primitive icy bodies) and how they relate to each other. For example, what constraints are imposed by a varying level of solar radiant and magnetic activity (e.g., faint early Sun)? Is Jupiter required to shield the Earth from impactors in order to develop life? Was water and organics delivered to the terrestrial planets by primitive icy bodies? Additional topics may relate to the formation and evolution of the planets. How do magnetospheres couple to atmospheres, and what is their role in holding an atmosphere against the solar wind, in the retention of water and simple hydrocarbons, and in the development of conditions favorable to life? What is the importance of impacts in the turnover and exchange of material from below the surface with the regolith and in the exchange of minerals and even primitive life forms between planets? How do dynamic planetary interiors, e.g. tectonics including molten cores and magnetic dynamos, lead to cycling of material between the interior and the atmosphere, (the carbon cycle on Earth and a possible methane cycle on Titan)?

- Earth processes or systems that are good analogs for processes or systems at work elsewhere in the solar system. Studies conducted on Earth might improve the understanding of what goes on elsewhere and build a broad multi-planet

perspective. Such studies could include: cryospheric processes in relation to icy moons and polar caps; oceanographic processes in relation to magnetic field signatures, tides, and seismicity; atmospheric processes in relation to dust and aerosols, cloud formation, and precipitation; and geomorphological processes in relation to life signatures and tectonics. Studies of processes embedded in a planetary systems perspective would be appropriate, as would interdisciplinary studies that emphasize the close links among tectonic, biological and surface environmental systems and their evolution.

- Prebiotic chemistry and the cycling of elements. Research on the chemistry of organics and other biotic precursors can take advantage of laboratory tools and manipulations, samples from other bodies, spectroscopic observations, or modeled systems in order to understand better the origins of life and assist in the search for biosignatures. Studies of meteorites and other primitive bodies may inform us about the evolution of our own solar system's protoplanetary disk.

- Understanding and modeling the space environments in which exploration activities will occur. This research is of importance to the Vision for Space Exploration and can encompass those aspects of the dynamic, particles-and-fields coupling between the Sun and regions of the solar system likely to be encountered by human and robotic missions. Studies could include the development of a predictive capability of estimating the likely radiation environment at, for example, the Lunar and Martian surfaces and those regions of space that will be transited by human exploration missions. Other topics include the quasi-steady magnetic connection of the Sun to likely regions of to be explored by NASA, the physical origins of solar drivers of severe space environmental effects, and fast coronal mass ejections and particle-generating flare events in the solar atmosphere and their propagation through interplanetary space, onto the surface of the Moon, and into the atmosphere of Mars. Studies may include investigations that develop first-principles and empirical models that can lead to improved forecasting and current situational awareness of these areas of space.

1.4 Relationship to Other NASA Programs

1.4.1 Space Radiation

The Space Radiation program element of the Office of Human Health and Performance in the Exploration Systems Mission Directorate is responsible for providing NASA with the information required to assure that radiation exposure in space does not exceed acceptable risk. This program supports research and development largely based on the use of charged particle beams to simulate space radiation. The program manages the NASA Space Radiation Laboratory (NSRL) operated by Brookhaven National Laboratory in Upton, NY, where facilities for physics and biology research are available to qualified investigators. NSRL delivers beams of ions of all energies and types corresponding to space radiation, and can also simulate complex particle and energy mixtures.

Investigations supporting the radiation program are solicited through a NASA research Announcement (NRA); the next solicitation is planned for Fall 2005. Information about NASA's biomedical research solicitations, including radiation, may be found at: http://nspires.nasaprs.com or http://research.hq.nasa.gov (see "Exploration Systems Mission Directorate" or "Office of Biological and Physical Research"). This site also offers "Research Task Books," which are searchable databases containing information about all of the life sciences research tasks.

Investigators interested in gathering preliminary data for submission of proposals to an NRA may obtain beam time at NSRL at no charge by submitting an experimental proposal and meeting all the Brookhaven access and safety requirements. This type of experiment is expected to require only a minimal amount of beam time and facility support, and may not to interfere with other investigations. The individual scientist interested in taking advantage of this possibility should contact the Chair of the Scientific Advisory Committee for Radiation, Dr. Betsy Sutherland at: bms@bnl.gov. Further information on NSRL is available at: http://www.bnl.gov/medical/NASA.

1.4.2 Origins of Solar Systems and Terrestrial Planet Finder Foundation Science

The Origins of Solar Systems program solicits basic research proposals to conduct scientific investigations related to understanding the formation and early evolution of planetary systems and to provide the fundamental research and analysis necessary to detect and characterize other planetary systems. These investigations may involve analytical and numerical modeling, laboratory research, and observational studies in the following areas: star formation and the relationship to planetary system formation, solar nebula processes, accumulation and dynamical evolution, analysis of primitive materials, and the detection of other planetary systems. This Origins of Solar Systems program realizes the existing potential for complementary interdisciplinary efforts to solve key scientific questions. To achieve this goal, proposals are encouraged that involve joint research efforts by investigators from different scientific communities.

The Terrestrial Planet Finder Foundation Science program solicits basic research proposals to conduct scientific investigations in support of the future Terrestrial Planet Finder (TPF) missions. Investigations are solicited that provide the scientific data and theoretical framework required to define the nature and scope of the TPF missions, the scientific data and theoretical framework required to refine the TPF target list, and the theoretical background required to plan the missions and to interpret the data obtained.

More information on the Origins of Solar Systems program may be found in Appendix B.4 of this NRA, and more information on the Terrestrial Planet Finder Foundation Science program may be found in Appendix C.10 of this NRA.

1.4.3 Astrobiology

This NRA contains three programs in Astrobiology: the Exobiology and Evolutionary Biology Program (Appendix B.12), the Astrobiology Science and Technology Instrument Development program (Appendix B.16), and the Astrobiology Science and Technology for Exploring Planets program. The scientific goals and objectives of NASA's Astrobiology program are described in the Astrobiology Roadmap that is available on the Astrobiology web site at http://astrobiology.arc.nasa.gov/roadmap.

The goal of NASA's Exobiology and Evolutionary Biology program (Appendix B.12) is to understand the origin, evolution, distribution, and future of life in the Universe. Research is centered on the origin and early evolution of life, the potential of life to adapt to different environments, and the implications for life elsewhere. This research is conducted in the context of NASA's ongoing exploration of our stellar neighborhood and the development of biosignatures for *in situ* and remote sensing applications.

The Astrobiology Science and Technology Instrument Development program (Appendix B.16) requests proposals to develop instrumentation capabilities that will help meet Astrobiology science requirements on future space flight missions, as well as unique Astrobiology science objectives on Earth.

The Astrobiology Science and Technology for Exploring Planets program (Appendix B.17) solicits proposals for investigations to explore the Earth's extreme environments in order to develop a sound technical and scientific basis to search for life on other planets. A unique feature that is central to the ASTEP program is the use of terrestrial field campaigns to further science and technology.

2. Programmatic Information

Proposers to the IES Program must propose an interdisciplinary investigation that supports one of the interdisciplinary research themes given in Section 1.3, or proposes any other innovative investigation that is explicitly interdisciplinary in nature and linked to the goals, objectives, or missions of NASA's space exploration program. The investigation may lead to knowledge, techniques, mission concepts, or other outcomes that enable the goals and objectives of NASA's space exploration program stated earlier. Alternatively, the investigation may lead to knowledge, techniques, mission concepts, or other outcomes that will be enabled by the successful conduct of any aspect of NASA's space exploration program. That is, successful proposers must demonstrate in the proposal that their investigation either enables, or is enabled by, NASA's exploration program.

Proposed investigations may require advanced techniques and capabilities. Investigations that include the development of required advanced techniques and capabilities are also solicited. Potential advanced techniques and capabilities include application of computer science and related technologies that foster an interdisciplinary approach for merging science data and models with advanced analysis and interpretation techniques; automated

detection and characterization of markers in complex, coupled systems; or collaborative tools for distributed research.

Those investigators whose research requires high performance computing should refer to the *Summary of Solicitation*, Section I(b), *"NASA-provided High-end Computating Resources."* This section describes the opportunity for successful proposers to apply for computing time on either of two NASA computing facilities, the 1392-processor Alpha SC45 at Goddard Space Flight Center's Earth and Space Data Computing Division, or the new 10,240-processor (twenty 512-processor SGI Altrix's) Project Columbia supercomputer at NASA/Ames Research Center's Advanced Supercomputing Division.

Proposers are reminded that the evaluation criteria for this solicitation are given in the *NASA Guidebook for Proposers* (see below for reference). These criteria are relevance to NASA's strategic goals and objectives, intrinsic merit, and cost realism and reasonableness. In addition to the factors given in the *NASA Guidebook for Proposers*, the evaluation criterion "relevance to NASA's strategic goals and objectives" specifically includes the following factors:

- The degree to which the proposed investigation either enables, or is enabled by, the goals of NASA's exploration program.

In addition to the factors given in the *NASA Guidebook for Proposers*, the evaluation criterion "intrinsic merit" specifically includes the following factors:

- The value and necessity of including joint research efforts by investigators from different scientific communities, particularly from both Earth and space science;
- The extent to which the investigation takes full advantage of the existing knowledge or capabilities of traditional disciplines within Earth and space science in support of the goals and objectives of the Vision for Space Exploration;
- The progress that the investigation will make toward one or more of the goals and objectives of NASA's exploration program; and
- The degree to which the investigation directly advances the science and exploration objectives of the Vision for Space Exploration.

Proposers should propose a period of performance of one to three years beginning no earlier than October 1, 2005. This can be proposed in distinct phases, or as a continuum with distinct milestones, leading to subsequent phases/milestones.

Reporting requirements include an annual report submitted prior to the award anniversary date, as well as a final report upon completion of the period of performance. The Science Mission Directorate will hold a community symposium on exploration science during late 2005 or early 2006. It is expected that all Principal Investigators in the IES Program will participate in the symposium by presenting their approved investigation to the community including its linkage to NASA's space exploration program and progress-to-date.

A preproposal conference will be held in the Washington, DC, area in early April 2005. This conference will provide an opportunity for potential proposers to discuss the

objectives of the Interdisciplinary Exploration Science Program with NASA. It will also provide potential proposers the opportunity to form collaborations. Details of the preproposal conference will be posted as a clarification on the homepage of this NRA no later than 30 days in advance of the conference.

3. Additional Programmatic Information

3.1 Demonstration of Relevance to NASA's Objectives

Proposals for all of NASA sponsored research programs are judged on three criteria: Scientific and technical merit of the proposed work, cost realism and reasonableness, and relevance of the proposed work to NASA missions and science goals (see also Appendix C of the *Guidebook for Proposers Responding to NASA Research Announcement – 2005* at http://www.hq.nasa.gov/office/procurement/nraguidebook/). To enable the NASA Science Mission Directorate to properly evaluate the relevance of proposals submitted to its programs, as well as track its progress toward achieving its goals as mandated by the Government Performance Review Act (GPRA), it is mandatory that all research supported by NASA's programs demonstrate its relationship to NASA strategic goals and/or science objectives as stated in the latest version of its Strategic Plan; see the discussion in Section I(a) of the *Summary of Solicitation* of this NRA. Therefore, in addition to addressing the specific goals of this program, all proposers must provide as expository text in the main body of their proposal a statement of the relevance of their proposed work to NASA's *Strategic Objectives* given in Table 1 in the *Summary of Solicitation* of this NRA. This discussion need not exceed the order of a quarter page of text and is to be included in the introduction to the Science-Technical-Management section of proposal.

Note that this NRA references NASA's 2005 strategic objectives (see Section I(a) and Table 1 for references).

3.2 Summary of Key Information

Expected total program budget for new awards	~ $10M in FY06
Number of new awards pending adequate proposals of merit	~ 15-20
Maximum duration of awards	1-3 years; shorter term proposals are encouraged.
Page length for the central Science-Technical-Management section of proposal	15 pp; see also Chapter 2 of *Guidebook for Proposers Responding to NASA Research Announcement – 2005*

Submission medium and number of copies	Hard copy only (15 copies plus signed original); see also Chapter 3 of *Guidebook for Proposers Responding to NASA Research Announcement – 2005*
NASA Strategic Objective to which proposals to this program must state and demonstrate relevance	See Table 1 in the *Summary of Solicitation* of this NRA.
General information and overview of this solicitation	See *Summary of Solicitation* of this NRA.
Detailed instructions for the preparation and submission of proposals	*Guidebook for Proposers Responding to NASA Research Announcement – 2005* at http://www.hq.nasa.gov/office/procurement/nraguidebook/.
Web site for submission of proposal Cover Page:	URL: http://nspires.nasaprs.com (help desk available at nspires-help@nasaprs.com or (202) 479-9376)
Date of Pre-proposal Conference	Approximately April 2005 in the Washington DC area; details including date, time, and location will be posted on the homepage of this NRA at least 30 days in advance of the meeting.
Due Date for Notice of Intent to Propose	See Tables 2 or 3 in *Summary of Solicitation* of this NRA.
Due Date for delivery of proposals	See Tables 2 or 3 in *Summary of Solicitation* of this NRA.
Selecting Official	Deputy Associate Administrator, Science Mission Directorate
Address for the delivery of proposals	Interdisciplinary Exploration Science ROSES-2005 NRA Science Mission Directorate NASA Peer Review Services Suite 200 500 E Street, SW Washington, DC 20024 Telephone: (202) 479-9030
Point of contact concerning this program	Dr. Paul Hertz Assistant Associate Administrator for Science Science Mission Directorate NASA Headquarters Washington, DC 20546-0001 Telephone: (202) 358-0986 E-mail: Paul.Hertz@nasa.gov